A new risk assessment tool for multimodal transport of Dangerous Goods

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Abstract

At present time, future alpine railway crossings are under construction that will go through long tunnels, namely between France and Italy, the Modane base tunnel, and, in Switzerland, the Gotthard and Lötschberg base tunnels. Crossing large mountainous areas such as the Alps and the Pyrenees means a lot of difficulties to solve. Security issues in those long tunnels have to be dealt with. Other security issues are to be addressed when Dangerous Goods go through densely populated areas, others where different means of transport (route, rail, ...) are interfaced.

These evolutions will generate modifications in the means of transporting goods and also in the routes pattern. It is thus important to be able to evaluate the risks due to some goods, some means of transport on the routes. The present paper shows the INERIS ongoing research project relative to the assessment of the risk induced by the transport of Dangerous Goods by road, by rail, and by their combined means of transport. In this paper, the main features and models involved in the future multimodal QRA tool are presented.

1. Introduction

A tool, enabling to assess risks due to road transport, already exists. Within the framework of a research project carried out for both the Organisation for Economic Co-operation and Development (OECD) and the PIARC (World Road Association), INERIS has already developed a model of Quantitative Risk Assessment (QRA) relative to the transport of Dangerous Goods on roads including tunnel sections. This work has led to an operational tool for the road transport. At present time, this tool is recommended in the French regulation and used to realise comparative risk studies for roads eventually including tunnels, crossing more or less populated areas, with a more or less dense traffic.

The ongoing project will extend the risk assessment capabilities for multimodal means of transport. The future new tool will integrate a Geographical Information System in order to achieve comparative risk assessments for complex and long routes.

In this paper, the main features and models involved in the multimodal QRA model are presented.

In order to assess in a general way the risks relative to the transport of Dangerous Goods, it appears necessary to have a tool dedicated to the rail transport whether it is operated in the traditional way (wagons) or with rail-road transport.

2. General approach

2.1 The QRA Model

The main purpose of the QRA model is to assess the risks relative to the transport of Dangerous Goods in a quantitative way. The model evaluates simultaneously the consequences and the frequencies of occurrence of possible scenarios. This makes it possible to assess quantitatively the societal risk (if the distribution of the people liable to be exposed is at hand) and the individual risk.

A complete assessment of the risks due to Dangerous Goods would require to consider all the possible weather situations, all kinds of accidents with all types of vehicle partially or fully loaded, etc. Such an evaluation is completely impossible and some simplifications have to be introduced. The QRA model is based on the following steps:

- Choice of a restricted number of Dangerous Goods.
- Choice of some representative accidental scenarios implying those Dangerous Goods with their usual packagings.
- Identification of physical effects of those scenarios for an open air or a tunnel section.
- Evaluation of their physiological effects on road or rail users and local population.
- Taking into account of the possibilities of escape/sheltering.
- Determination of the yearly frequency of occurrence for each scenario.

2.2 F/N curve

F/N curves and their expected values are the major outputs of the QRA model. They are defined as follows:

Frequencies / Gravity curves (F/N curves): stand for the annual frequency of occurrence F to have a scenario likely to cause an effect (generally, the number of fatalities) equal to or higher than N.

Expected value (EV): number of fatalities per year, obtained by integration of a F/N curve

The risk is characterised by two main aspects: frequency of occurrence and consequences. Consequences can be expressed by a number of fatalities, of injuries, structure and building destruction, damages to the environment. The number of fatalities can be considered as the main criteria to quantify risks. Injuries can also be calculated. In order to determinate the societal risk, F/N curves are built. Structure damages are evaluated through a semi-quantitative way and environmental damages through a fully qualitative way.

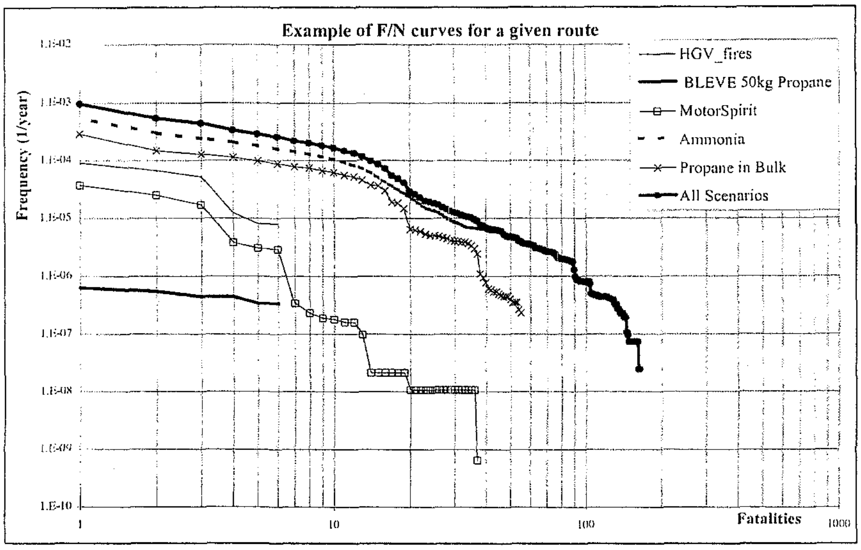


Figure 1: Example of F/N curves

3. *Road QRA Model*

The QRA model for the road is the origin of the multimodal QRA model because it was developed first and because even if there are significant differences, other tools will be based on the same underlying approach. Therefore an initial presentation of the Road QRA model enables to understand how the whole multimodal QRA model will be elaborated.

3.1 Integrated scenarios

The numbers of scenarios and of Dangerous Goods involved had to be very restricted for simplification purpose, but nevertheless be representative of the Dangerous Goods Transport. This challenge was met with a panel of 10 scenarios which have been developed in the QRA and are listed below:

Scenario Nr:	Description	Capacity of tank	Size of breach (mm)	Mass flow rate (kg/s)
1	HGV fire 20 MW	-	-	-
2	HGV fire 100 MW	-	-	-
3	BLEVE of LPG in cylinder	50 kg	-	-
4	Motor spirit pool fire	28 tons	100	20.6
5	VCE of motor spirit	28 tons	100	20.6
6	Chlorine release	20 tons	50	45
7	BLEVE of LPG in bulk	18 tons	-	-
8	VCE of LPG in bulk	18 tons	50	36
9	Torch fire of LPG in bulk	18 tons	50	36
10	Ammonia release	20 tons	50	36

Table 1: ***Scenarios of the road QRA Model***

Two scenarios relative to fires of Heavy Goods Vehicles not transporting Dangerous Goods were used because they represent a non negligible danger in tunnel and because their frequency of occurrence is far higher than that of scenarios involving Dangerous Goods.

In the open air, consequences of physical phenomena can be calculated by existing dedicated models. Consequences are calculated using percentages of lethality and/or injuries, using probit equations (Equation which allows to deduct the physiological consequences from the exposure to physical consequences of a phenomenon) and considering the possibility to escape or to get shelter.

Usually, open air models calculating consequences of scenarios can not be used in tunnels and a specific development has been made (with the collaboration of WS. Atkins, UK) to determinate:

- The tunnel zones which can be affected by the scenario,
- Effects that can overflow out of the tunnel and which can generate effects in the open air outside the tunnel.

The complexity of problems to deal with and the number of possibilities of equipment and ventilation system (longitudinal, transversal or semi-transversal ventilation, one or two tubes...) in the tunnels lead to use simplifications.

Adoption of appropriate measures to the tunnels (traffic management, flammable liquids drainage, construction dispositions, monitoring, etc.) can reduce the frequency of the accidents and their severity. Some of them have been taken into account in the sub-module dedicated to the tunnels and in the QRA model. Therefore, it is possible to assess their influence on the F/N curves and on risk levels and to make more relevant decisions to reduce the risks.

3.2 QRA model Use

The main use of the QRA model is to compare the risks due to transport of Dangerous Goods on various routes. Typically, for a route including a tunnel, there could be other routes called alternatives routes, which are usually longer or going through urban centres. The method enables to assess the risks due to the Dangerous Goods traffic on each route. A comparison based on F/N curves and expected values becomes then possible.

When displayed on the same graph, if the curves of the various routes do not intersect, the riskier route is the one whose F/N curve is above the other curves.

If the curves intersect, the difference between the expected values has to be analysed. If they are significantly different, a conclusion is possible, else other decision criteria may be taken into account.

In order to use the model, data must be collected concerning:

- Tunnel: its geometry, its ventilation, its equipment
- Traffic of vehicles according to estimations or observations (Dangerous Goods, heavy goods vehicle, light vehicles, bus and coaches)
- Rate of accidents for each route
- Populations outside of the tunnel
- Meteorological conditions
- Planned exploitation procedures in case of accident and time to implement them

An accurate description of the traffics on each route is a key factor for a good use of the QRA model.

4. Multimodal QRA Model

4.1 General approach

In order to be able to apprehend in a general way the risks due to the transport of Dangerous Goods, it appears necessary to have a tool dedicated to the rail transport and a tool which can include the various means of transport on a given route. For the rail transport, it is necessary to distinguish the "ferroutage" (HGVs loaded on carrier wagons) and the traditional rail transport.

Thus the project presently under development has two principal aims:

- Develop a model of Quantitative Risk Assessment relative to the transport by rail of Dangerous Goods dealing with "ferroutage" as well as traditional rail transport. The exposed populations are the populations located in the vicinity of the railroads (sedentary people or moving people in the case of routes skirting and/or crossing the railways) and the travellers aboard trains. In this last case, it may be people aboard freight trains (it is typically the case of HGV drivers, in the case of ferroutage) or in passenger trains. The case of the long tunnels, where several trains (including eventually passenger trains) can a priori be simultaneously present will be treated.
- Create a common interface for the assessment of road and railway risks with the help of a Geographical Information System (GIS) to allow calculations of risks on a route independently of the means of transport, rail or road, open area or tunnel.

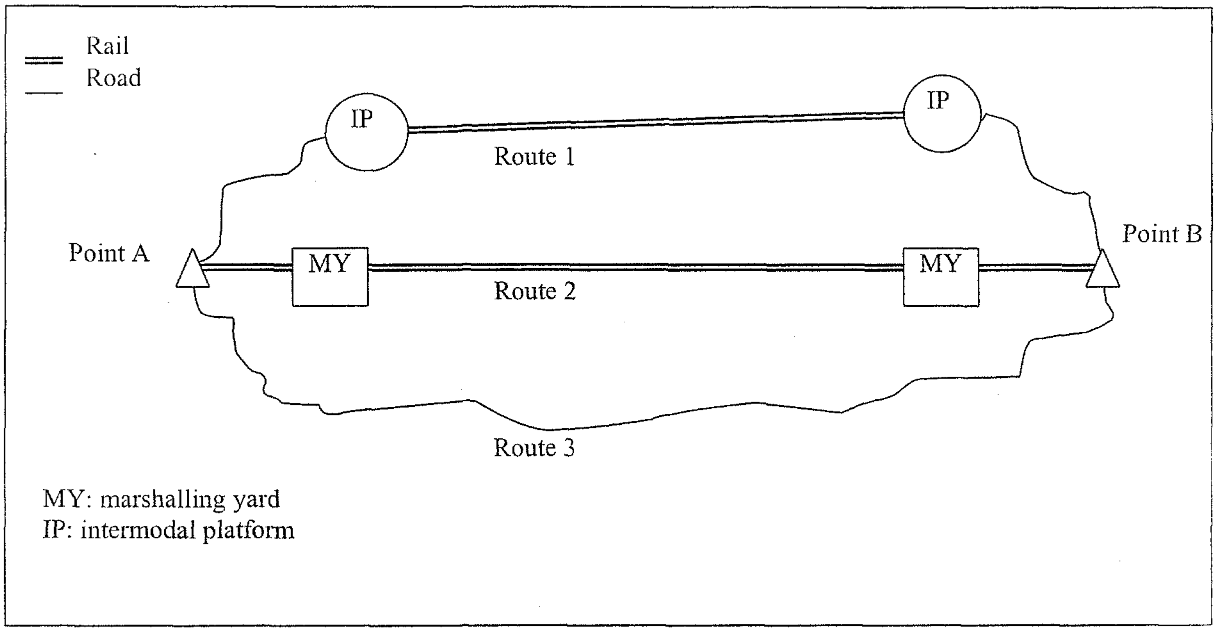
These developments will be integrated with the road QRA model into a global tool : the multimodal QRA model. This global model will make it possible to study complex and realistic routes regarding the road and rail transport of Dangerous Goods.

4.2 The notion of route

Transport of Dangerous Goods in France may be done by various modes:

- road transport,
- traditional railway transport,
- intermodal transport, either combined transport (using containers which may be loaded on specifically road trailers or rail wagons) or “ferroutage”.

A route linking 2 point A and B is a succession of installations, ways or roads between those 2 points. For modelling purpose, it is considered these elements are separated by nodes which may be **inter or intra-modal nodes**. Points A and B are, most of the time, industries or industrial zones.



Route 1: Intermodal. On the route from an intermodal platform to another one, there can be marshalling yards.
Route 2: Rail transport. There can be some marshelling yards.
Route: Road transport.

Figure 2: Example of alternative routes

For rail freight, the unit of transport is the train, whereas the unit of loading is the wagon. If a company sends a sufficient number of wagons, it can constitute a whole train. A whole train goes directly from the shipper to the consignee without treatment by marshalling yards.

The transport of isolated wagons or of railboxes from intermodal transport requires the formation of trains. In order to form trains, wagons or railboxes are regrouped from the sending zones. These operations require to sort the wagons and recombine them in trains accordingly to their destination.

These operations are performed accordingly to the modes in:

- The intermodal platforms (interface between rail and road or road and rail),
- The marshalling yards (rail transport).

The concentration (geographical close vicinity of a large number) of railboxes raises the question of the potential "domino" effects: an explosion and/or a fire can damage the wagons or the railboxes which are close. If they contain Dangerous Goods, the damage caused by the first event can trigger an explosion, a fire or a toxic release on a second tank, and this propagation may go on. It is what is meant by domino effects.

Sources of danger relative to intermodal platforms are: the handling, which can results in falls and deteriorations of the railboxes, and the simultaneous presence of the road and railway, with manoeuvrings of trucks and trains. Dangerous Goods spillage or release due to overloads and bad weight distribution of loadings are the main causes of danger on these platforms.

Between the marshalling yards and the platforms, points of junction of routes and sometimes of parking for trains are to be found. They present particular characteristics either in term of accidentology, or in term of consequences of a dreaded event, and are called "**singular points on line**".

The singular points in lines are:

- The railway crossings,
- The switching zones (rail),
- The passenger railway stations,
- The deep cuttings railroad,
- The bridges (rail and road),
- The tunnels (rail and road).

4.3 Integration of a GIS

"GIS" stands for "Geographical Information System". Geographical information is the representation of a portion of area, either by a diagram (geometrical figure), or an image. This representation is georeferenced, i.e. all the data are localised in the same frame of reference.

The major part of the data handled by the QRA (input and output data) has a geographical component. Replacing them in their context gives them a full dimension. The cartographic approach will optimise the exploitation of the QRA by widening its range and its fields of use. Also it will simplify the data collection needed for the risk assessment, i.e. the routes data and their environment, essentially the populations liable to be exposed.

This cartography will make it possible to represent in a synthetic way analyses implying many variables. It is possible to juxtapose multiple levels of information (densities of population, traffic, characteristics of the road or way (presence of tunnel or not, etc), scenarios considered, etc.) on a map. This cartographic approach may be a real help in decision-making.

4.4 Structure of the multimodal QRA model

Considering what has been written above, the general structure of the future multimodal QRA model is described in the figure below:

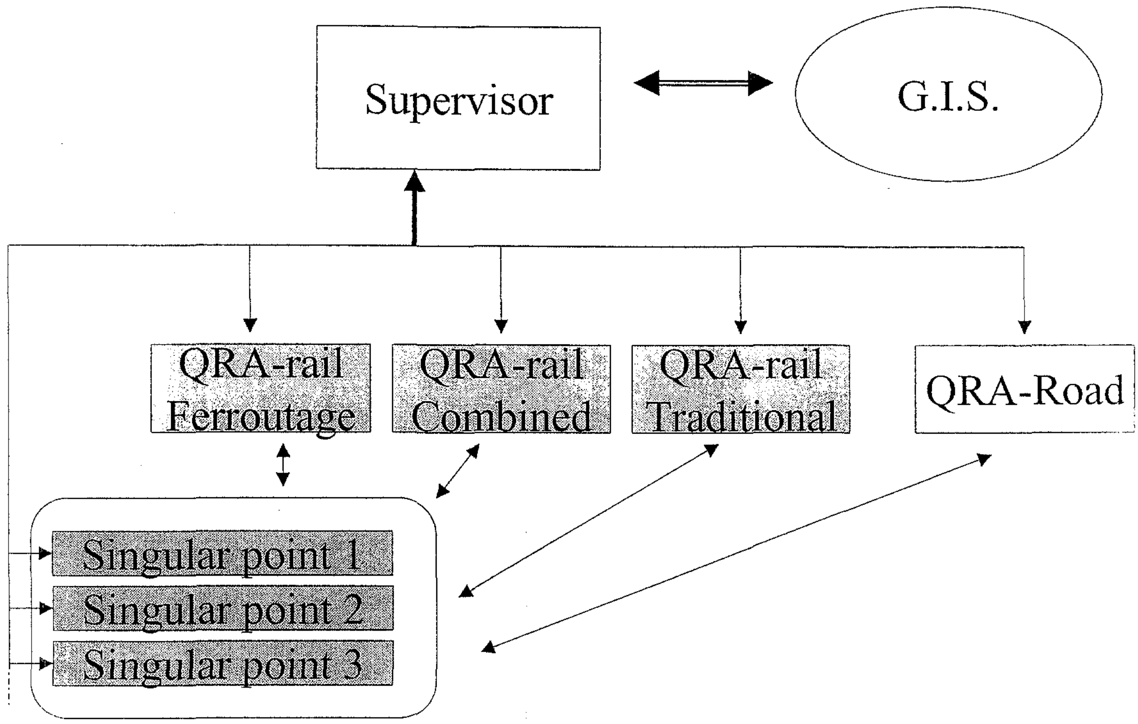


Figure 3: Structure of the future Multimodal QRA model

5 Rail QRA

5.1 General approach

The rail QRA model will be elaborated using an approach similar to the one used for the road QRA model. But it will require the development of new "sub- modules", specific to the railway routes. On certain aspects, a direct adaptation from the Road QRA model is not possible. For instance road traffic, constituted by a large number of vehicles may be described as continuous. On the other hand, rail traffic constituted by trains appears as essentially discontinuous.

In the model, three different modes have to be considered:

- The traditional Rail Transport

The goods are transported in tanks for the liquids or the gases under pressure especially designed for the rail transport, which constitute full wagons. Their capacity is higher than that of the tanks used for combined transport or road transport.

- Combined transport

With this type of transport, the freight, during its conveyance from an origin point towards a destination, uses several means of transport (maritime, road, railway). These changes of means of transport imply the use of Intermodal Units of Transport (IUT) which are sorts of specifically designed containers. The IUTs are loaded and unloading from one mean of transport to the other, either in intermodal platforms (rail-road) or in harbours (sea-rail or sea-road).

- The ferroutage

The ferroutage is an intermodal transport between rail and road. The whole HGV (trailer + tractor) is loaded on the wagon, contrary to the combined transport. In France it is used only for Transmanche transport (Channel tunnel), but is destined to develop in the future (for example the future Lyon-Turin rail link).

6 Conclusions

The project started in 2001 and will be achieved in 2003. At present time, the rail QRA model and the GIS approach for the road QRA model are under development.

All this work, supported by the French Ministry of Land Use Planning and Environment, and by the French Ministry of Transport, will lead to a new tool for the multimodal Quantitative Risk Assessment for the transport of Dangerous Goods.

Present developments will broaden the possibilities and the scope of the already existing road QRA model. In the fields of Risk Assessment relative to the Dangerous Goods transport, comparisons between different routes and means of transport will become possible.